

# **Maryland Upper Western Shore**

## **Final Version for 1985-2002 Data**

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Tidal Monitoring and Analysis Workgroup  
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#### **Maryland Upper Western Shore Basin Characteristics**

The basin drains an area of 685 square miles, including all of Harford County and portions of Carroll, Baltimore, and Cecil Counties. Larger water bodies include the Susquehanna River, Bush River, Gunpowder River, Little Gunpowder Falls, Deer and Octoraro Creeks, Conowingo Pool, Loch Raven and Pretty-boy Reservoirs and tidal embayments in the lower portions of the basin, including Middle River. Most of this basin lies in the Piedmont physiographic province, but some of it lies in the Coastal Plain province.

Census population from 2000 for the basin is 487,000. Major population centers in the Upper Western Shore include Bel Air South, Carney, Middle River, Edgewood, and Perry Hall.

Agricultural land and forest/wetlands are the dominant land uses in the basin (38 percent each). Urban land comprises 25 percent of the Upper Western Shore.

About 38 percent of the Upper Western Shore is in agricultural land. A series of best management practices have been planned to help reduce non-point source loads. BMP implementation for animal waste management, nutrient management plans, conservation tillage and cover crops, forest conservation and buffers, shore erosion control, marine pumpouts, and stormwater management retrofits and conversion are making good progress toward Tributary Strategy Goals. For other issues, such as treatment and retirement of highly erodible land, runoff control, stream protection, erosion and sediment control, septic connections and pumping, and urban nutrient management, progress toward Tributary Strategy Goals has been slower.

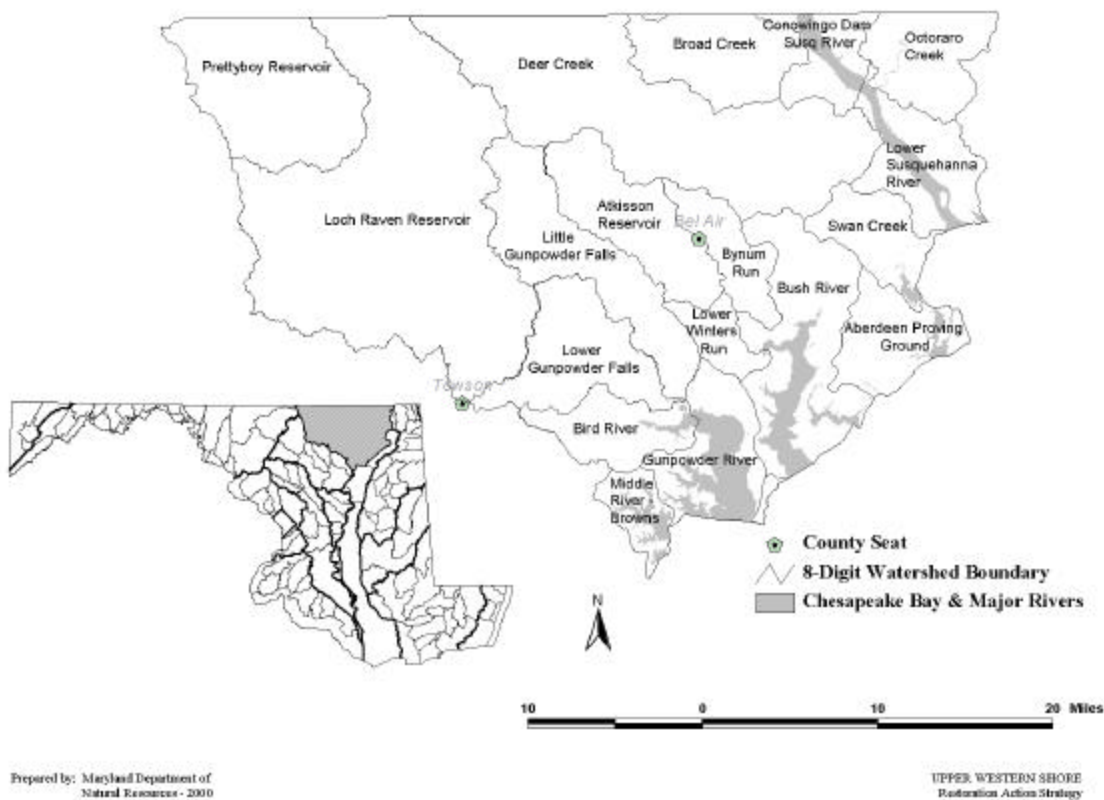
Urban land comprises a quarter of the Upper Western Shore. Of this developed land, 85 percent is classified as low intensity development. Five percent is high intensity, and 11 percent is commercial development.

Nearly 80 percent of the housing in the basin is in urban areas, with most of the remainder in rural areas. Slightly lower percentages of housing rely on municipal water and sewer systems, with 70 percent of the basin's housing using a public water source and 75 percent relying on a public sewer. Despite these statistics, point sources are not among the most significant pollutant sources in the basin. There are five major

wastewater treatment facilities in the Upper Western Shore basin, and biological nutrient removal has been implemented at four of them. Appendix A contains graphs of average monthly nutrient loads from the basin's major wastewater treatment facilities.

As of 2002, the most significant contributor of nitrogen to Maryland's Upper Western Shore was agricultural sources. These account for 39 percent of the basins' nitrogen load (Figure UWS2). Point sources contribute 21 percent and urban sources account for 18 percent of the basin's nitrogen load. For phosphorus, the largest contributor was agriculture (33 percent) (Figure UWS3). Urban sources, mixed open lands, and point sources contributed 30, 18, and 16 percent, respectively. The major contributor of sediment loads in the basin was agricultural land (69 percent). Urban, forested, and mixed open lands each made much smaller contributions (14, 10, and 7 percent respectively).

**Figure UWS1 – Map of Maryland's Upper Western Shore Basin**



**Figure UWS2 – 2000 Land Use in the Upper Western Shore Basin**

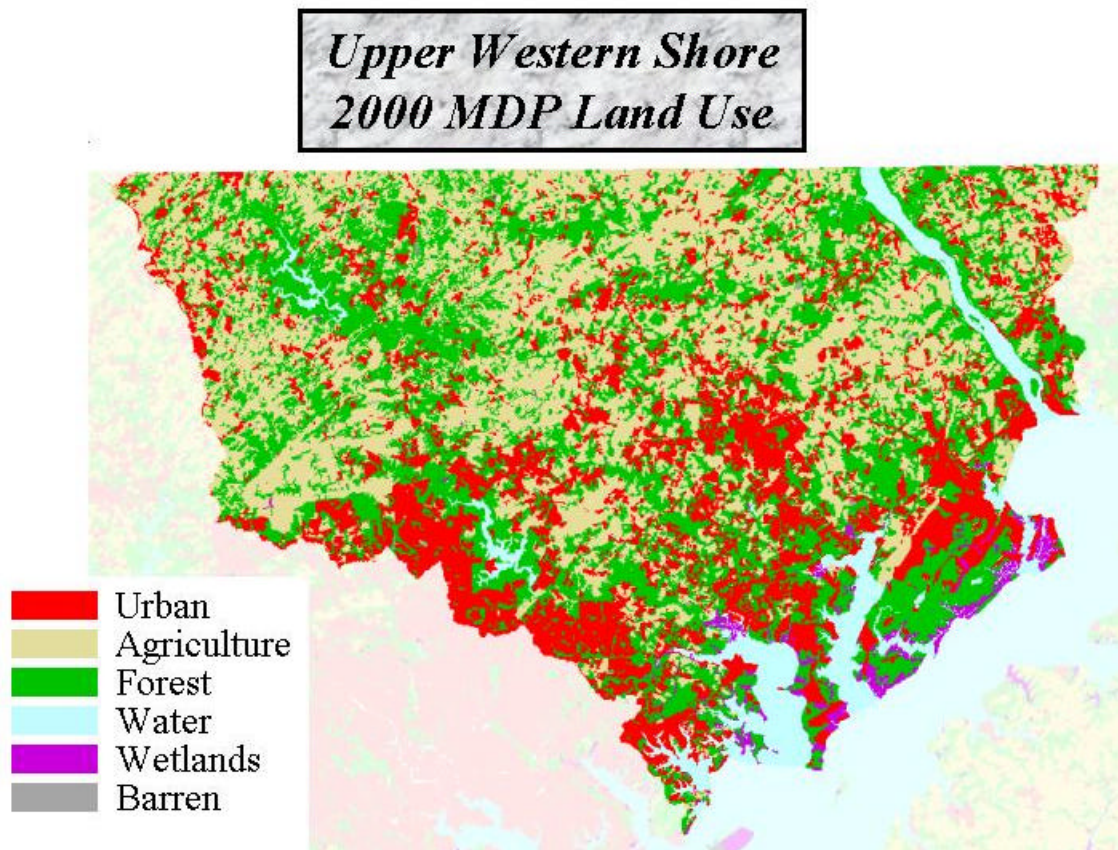
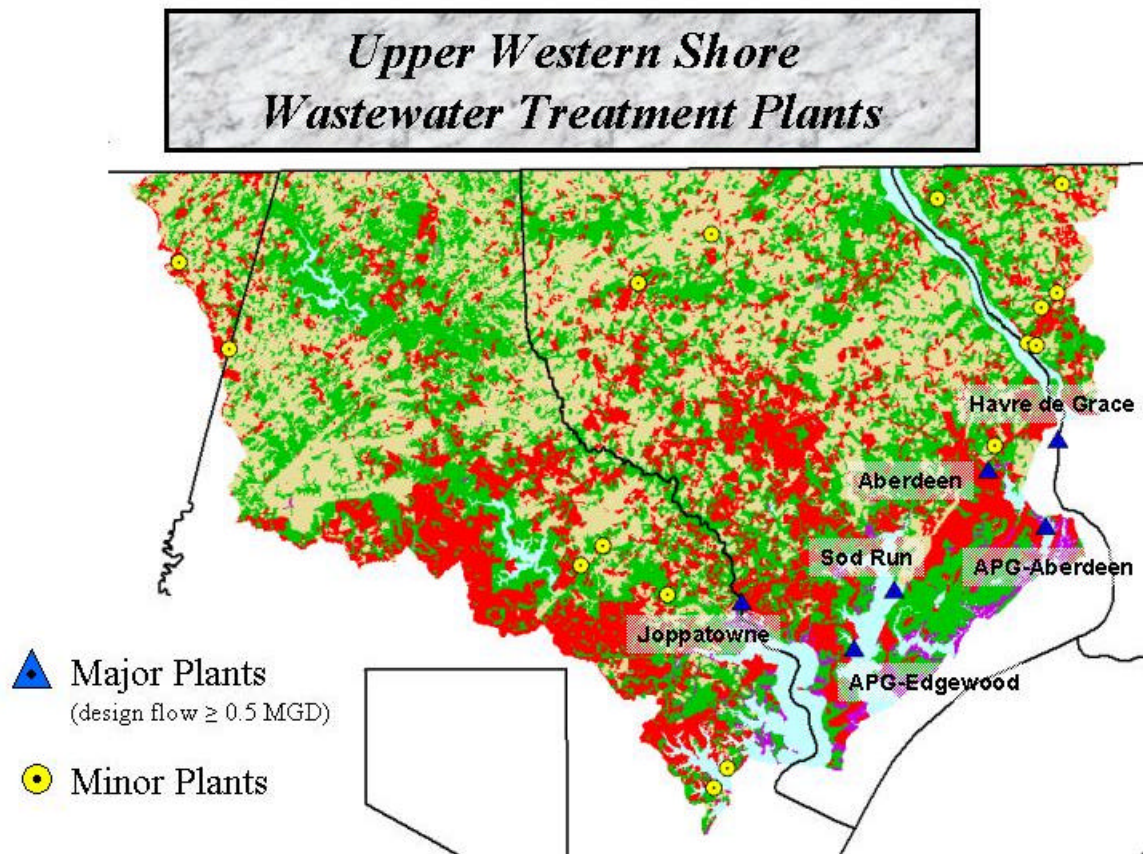
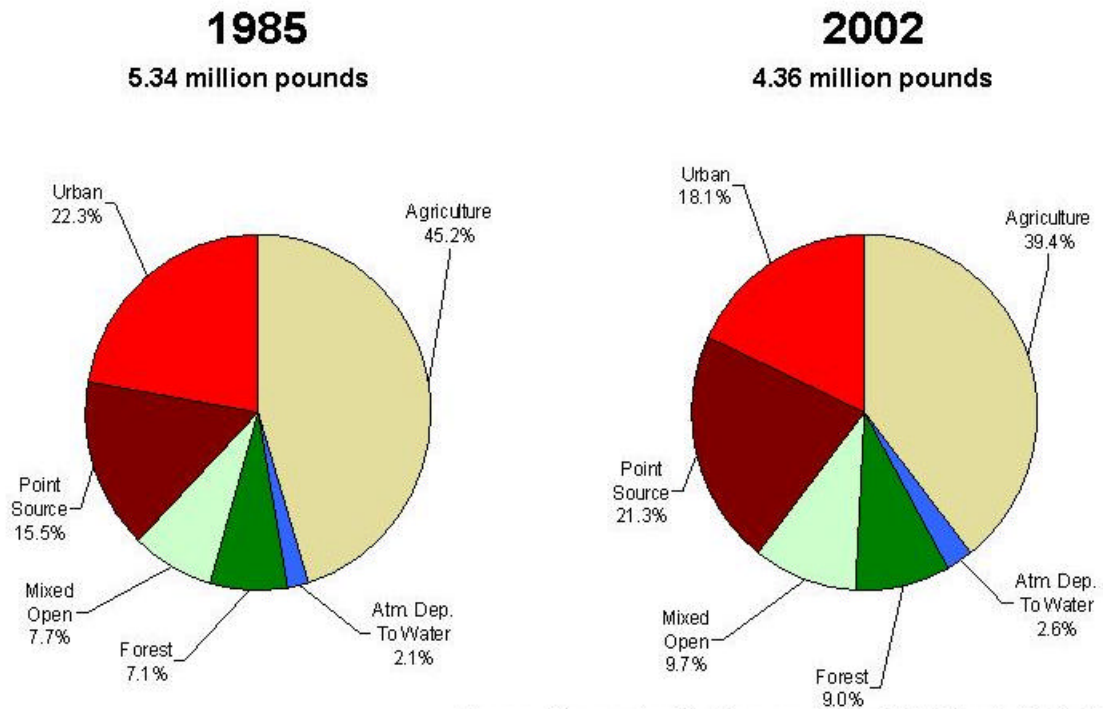


Figure UWS3– Wastewater Treatment Plants in the Upper Western Shore Basin



**Figure UWS4 – 1985 and 2002 Nitrogen Contributions to the Upper Western Shore by Source.**

### **Nitrogen Contribution of Upper Western Shore by Source**

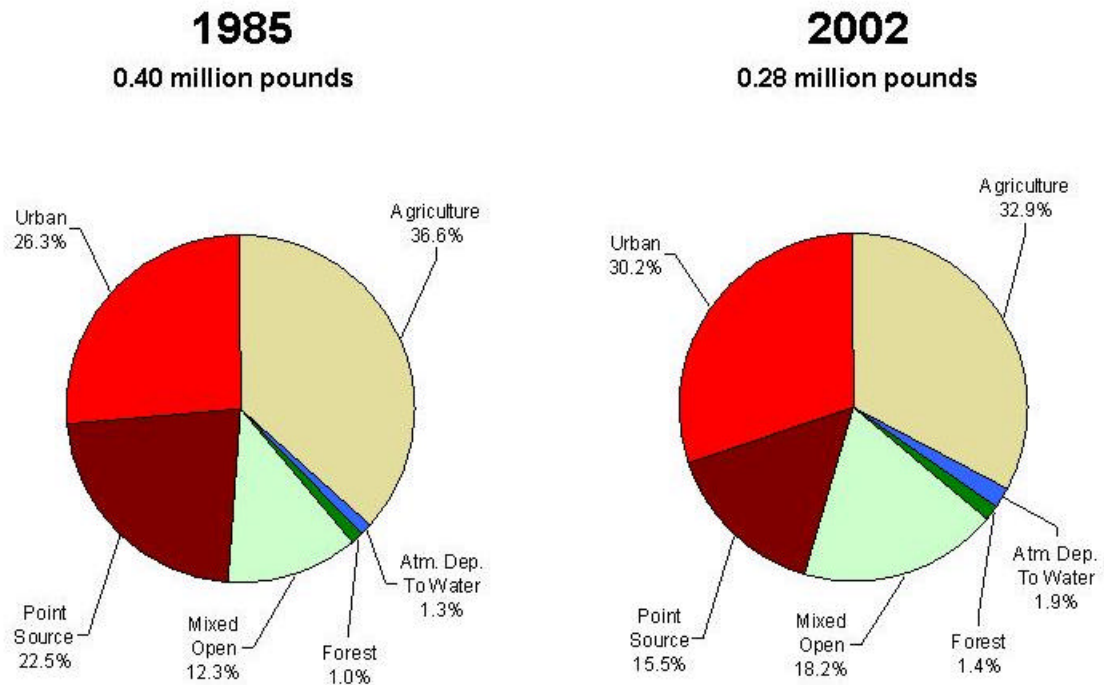


Source: Chesapeake Bay Program Phase 4.3 Watershed Model



**Figure UWS5 – 1985 and 2002 Phosphorus Contributions to the Upper Western Shore by Source.**

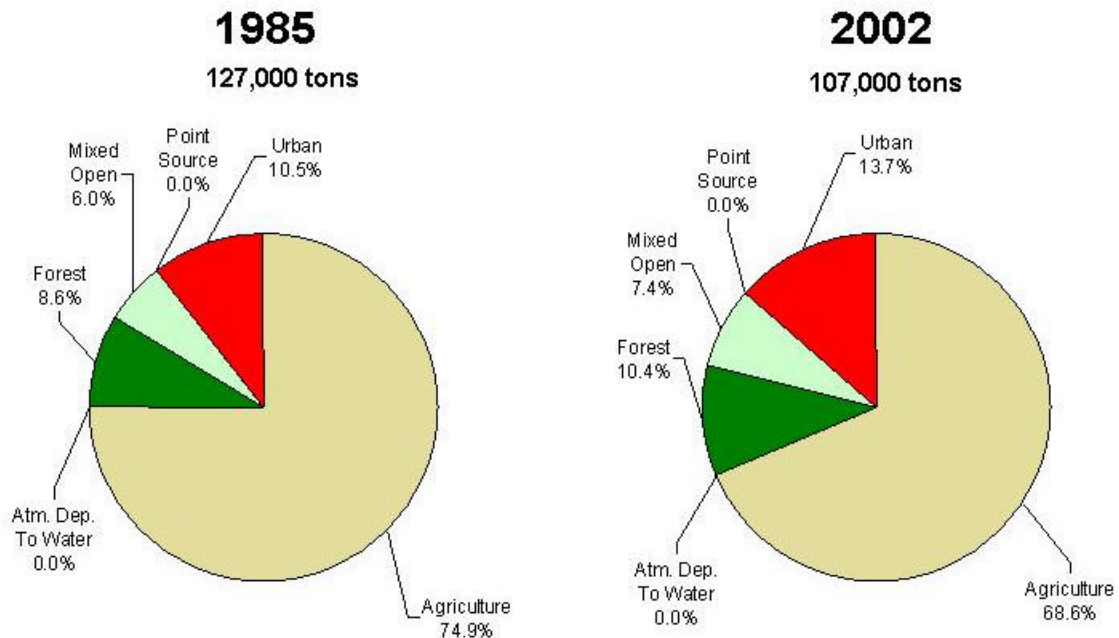
### Phosphorus Contribution of Upper Western Shore by Source



Source: Chesapeake Bay Program Phase 4.3 Watershed Model

**Figure UWS6 – 1985 and 2002 Sediment Contributions to the Upper Western Shore by Source.**

### **Sediment Contribution of Upper Western Shore by Source**



Source: Chesapeake Bay Program Phase 4.3 Watershed Model

Figure UWS7 – Total Nitrogen Status and Trends.

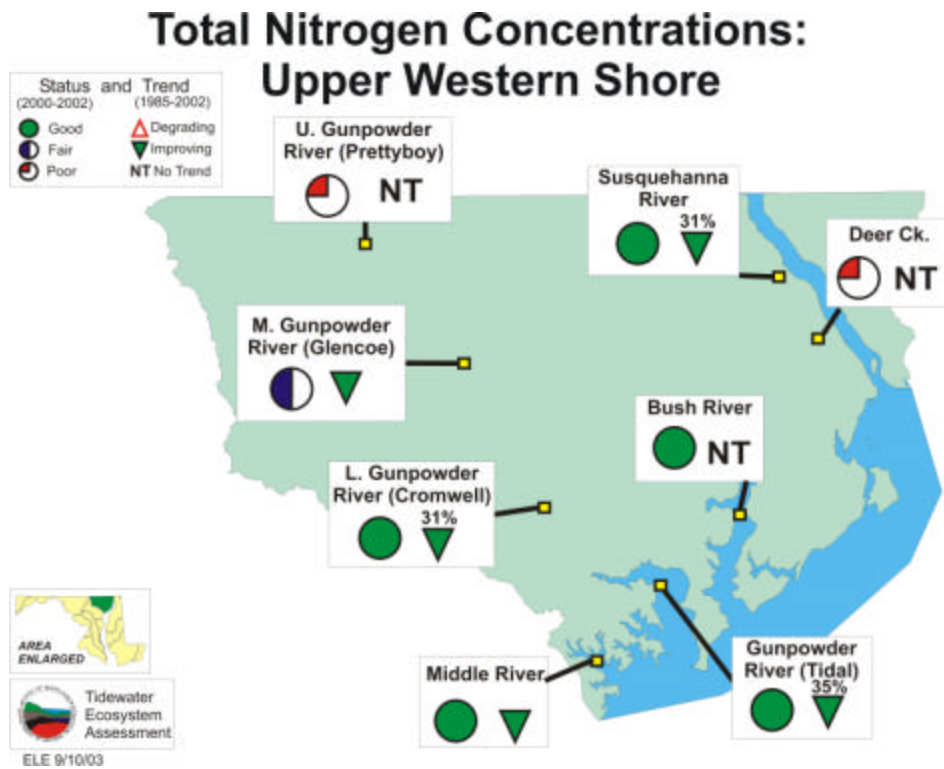


Figure UWS8 – Total Phosphorus Status and Trends.

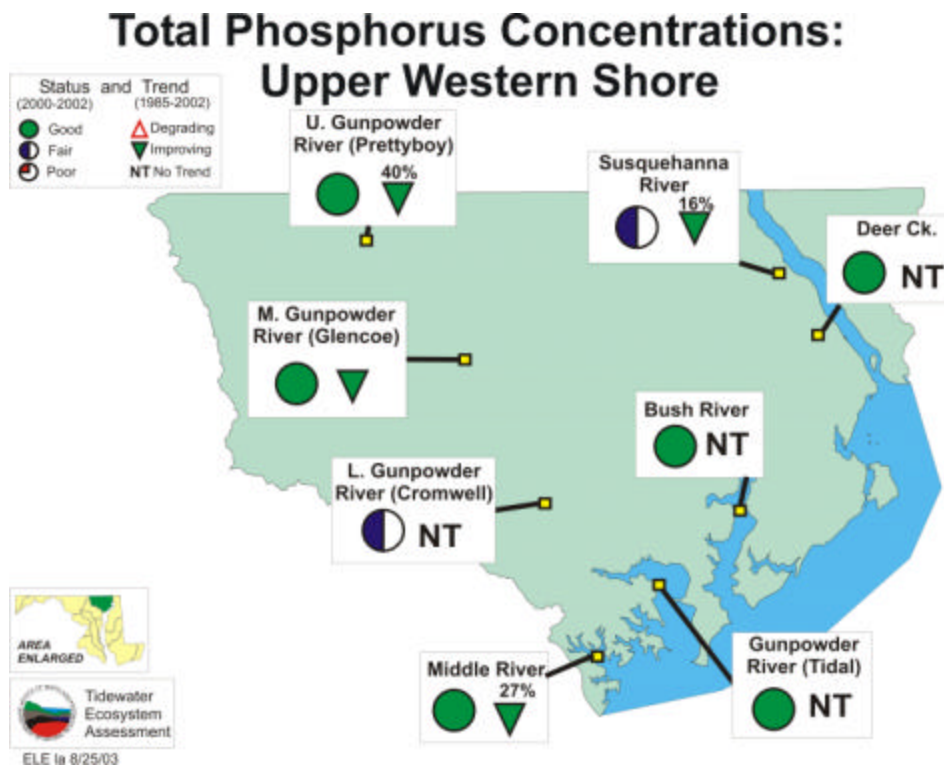




Figure UWS9 – Chlorophyll *a* Status and Trends

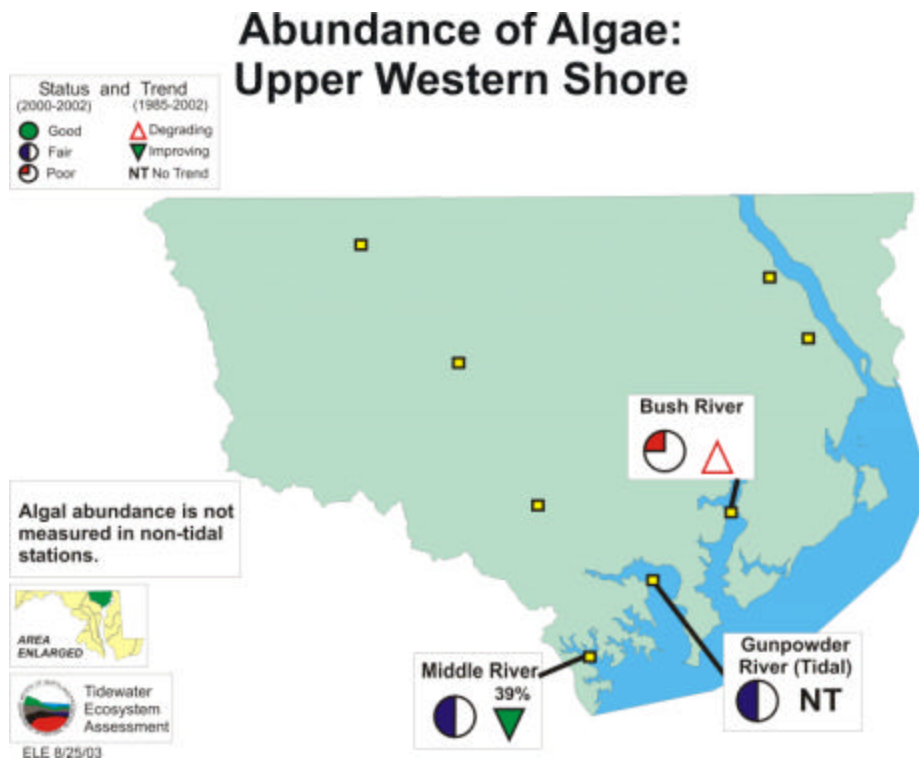


Figure UWS10 – Total Suspended Solids Status and Trends.

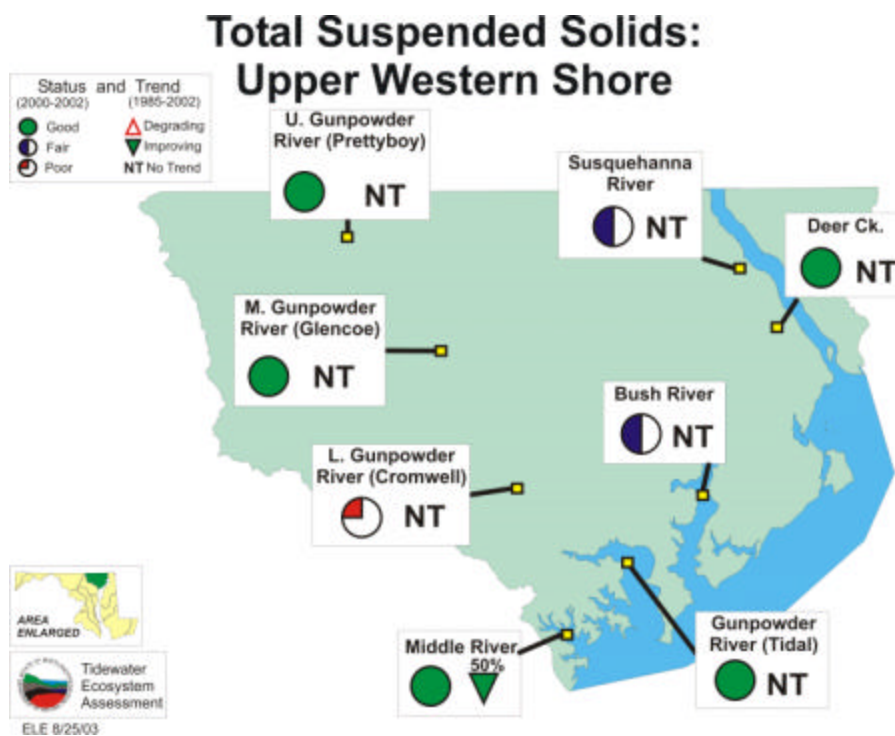


Figure UWS11 – Water Clarity (Secchi Depth) Status and Trend

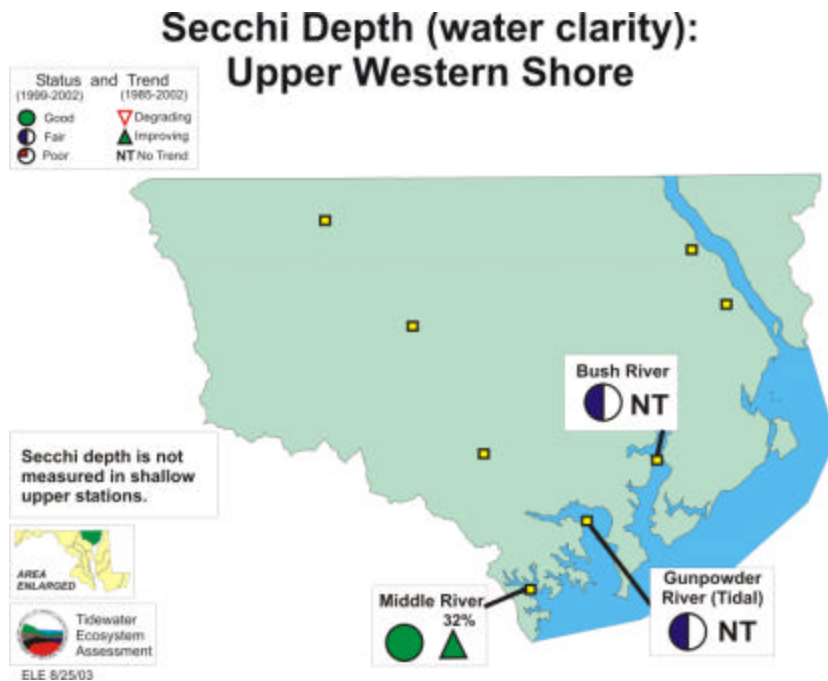
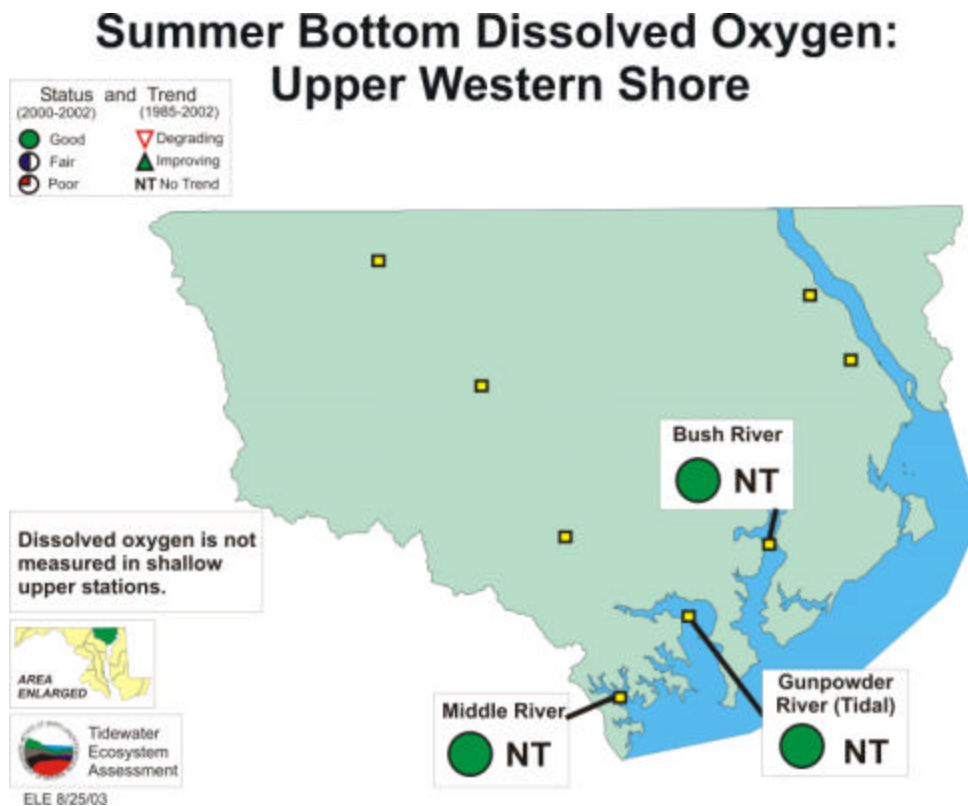


Figure UWS12 – Summer Dissolved Oxygen Status and Trends



## Overview of Monitoring Results

The following sections present results from monitoring four aspects of the ecosystem: water and habitat quality, submerged aquatic vegetation (SAV, i.e., bay grasses), the benthic (bottom-dwelling) community, and nutrient limitation. Unless otherwise noted, the data are from the State of Maryland's long-term monitoring programs.

### Water and Habitat Quality

#### *Non-tidal Water Quality Monitoring Information Sources*

Much useful information on non-tidal water quality is available on the Internet. The State of Maryland's Biological Stream Survey (MBSS) basin fact sheets and basin summaries are available at:

[http://www.dnr.state.md.us/streams/mbss/mbss\\_fs\\_table.html](http://www.dnr.state.md.us/streams/mbss/mbss_fs_table.html)

MBSS also reports stream quality information summarized by county at:

[http://www.dnr.state.md.us/streams/mbss/county\\_pubs.html](http://www.dnr.state.md.us/streams/mbss/county_pubs.html) In addition to these reports and fact sheets, detailed and more recent information and data are also available on the MBSS website: <http://www.dnr.state.md.us/streams/mbss>

Water quality information collected by Maryland's volunteer Stream Waders is available at: [http://www.dnr.state.md.us/streams/mbss/mbss\\_volun.html](http://www.dnr.state.md.us/streams/mbss/mbss_volun.html)

#### *Long-term Water Quality Monitoring*

Good water quality is essential to support the animals and plants that live or feed in the Lower Western Shore tributaries. Important water quality parameters are measured at five long-term tidal monitoring stations in the Lower Western Shore, including nutrients, water clarity (Secchi depth), dissolved oxygen, total suspended solids, and algal abundance.

Current status is determined based on the most recent three-year period (2000-2002). For dissolved oxygen, the current levels are compared to ecologically meaningful thresholds to assign a status of good, fair, or poor. Thresholds have not been established for the other parameters, so the current data are compared to a baseline data set, and assigned a status of good, fair, or poor, which is only a *relative* status compared to the baseline data. Trends are determined using a non-parametric test for trend (the Seasonal Kendall test). For a detailed description of the methods used to determine status and trends, see [http://www.dnr.state.md.us/bay/tribstrat/status\\_trends\\_methods.html](http://www.dnr.state.md.us/bay/tribstrat/status_trends_methods.html).

Total nitrogen and total phosphorus are relatively good at the tidal monitoring stations. Total nitrogen has decreased at the Gunpowder tidal station and total phosphorus has decreased at the Middle River station. Algal levels are poor and have worsened somewhat at the Bush River station, but have improved at the Middle River station and are relatively fair. Total suspended solids have decreased and water clarity has improved

at the Middle River station. Dissolved oxygen levels are good at the tidal stations and no trends are evident.

Note that the Glencoe station is between Pretty Boy and Loch Raven reservoirs; Cromwell station is just below the Loch Raven dam. Middle River has low freshwater flow resulting in a poorly flushed system.

Unspecified toxic pollutants caused waterbodies on and around Aberdeen Proving Grounds (Bush River) have caused the waters to be listed as impaired; elemental phosphorus from nonpoint sources caused Spesutie Narrows to be listed as well. Elevated copper and BHC levels have been found in some areas.

## SAV

The well-defined linkage between water quality and submerged aquatic vegetation (SAV) distribution and abundance make SAV communities good barometers of the health of estuarine ecosystems. SAV is important not only as an indicator of water quality, but it is also a critical nursery habitat for many estuarine species. Blue crab post-larvae are 30 times more abundant in SAV beds than adjacent unvegetated areas. Similarly, several species of waterfowl are dependant on SAV as food when they over-winter in the Chesapeake region.

The Chesapeake Bay Program has developed new criteria for determining SAV habitat suitability of an area based on water quality. The **A**Percent Light at Leaf **@** habitat requirement assesses the amount of available light reaching the leaf surface of SAV after being attenuated in the water column and by epiphytic growth on the leaves themselves. The document describing this new model is found on the Chesapeake Bay Program website ([www.chesapeakebay.net/pubs/sav/index.html](http://www.chesapeakebay.net/pubs/sav/index.html)). The older **A**Habitat Requirements **@** of five water quality parameters are still used for diagnostic purposes. Re-establishment of SAV is measured against the **A**Tier 1 Goal **@**, an effort to restore SAV to any areas known to contain SAV from 1971 to 1990.

The Bush River has had only periodic SAV occurrence ([www.vims.edu/bio/sav/](http://www.vims.edu/bio/sav/)), though there was a phenomenal expansion of SAV in 2000, to 194 acres, or 336% percent of the Tier I goal (Figure UWS13). Due to flight restrictions following the September 11, 2001 terrorist attacks, no data were collected for 2001. In 2000, the bulk of the SAV was located in Church Creek, Kings Creek, Dove's Cove, near Wilson Point, Towner Cove and Redman Cove. Ground-truthing throughout the river by the Aberdeen Proving Ground environmental staff and citizens has found 13 species, with the three most common being; milfoil, coontail and wild celery. From water quality-monitoring data obtained from the station located at the railroad bridge near Gum Point indicates that percent light at leaf, light attenuation and the concentrations of algae and suspended solids fail the SAV habitat requirements. Nitrogen is not applicable in this oligohaline environment. Only phosphorous levels meet the habitat requirements.

The Gunpowder River had generally low abundance of SAV ([www.vims.edu/bio/sav/](http://www.vims.edu/bio/sav/)) until 1996 (Figure UWS13). In 1996, 1997, 1998 and 2000, the SAV Coverage exceed

the Tier I goal of 865 acres, in fact the 2000 coverage was 2.8 times greater than the Tier I goal. Due to flight restrictions following the September 11, 2001 terrorist attacks, no data were collected for 2001. Typically, most of the SAV is found throughout the Dundee/Salt peter Creek complex and Days Cove areas with fringing beds in much of the Gunpowder. Ground-truthing throughout the river by the Aberdeen Proving Ground environmental staff and citizens has found 14 species, with the three most common being; milfoil, wild celery and coontail. The Department of Natural Resources has been removing the invasive floating plant, water chestnut from the Bird River. Water chestnut is an exotic species that can out compete native submerged species. The spiked seeds of this plant can also pose a hazard to people swimming or water skiing in the area ([http://www.dnr.state.md.us/bay/sav/water\\_chestnut.html](http://www.dnr.state.md.us/bay/sav/water_chestnut.html)). From water quality monitoring data obtained from the station located at the railroad bridge near Oliver Point indicates that percent light at leaf, light attenuation fail the SAV habitat requirements while the concentrations of algae and suspended solids are borderline (nitrogen is not applicable in this oligohaline environment). Only phosphorous concentrations meet the habitat requirements.

Middle River has had fairly variable SAV coverage over the last 15 years. Year 2000 had the highest coverage of SAV recorded by the aerial survey (740 acres or 86% of the Tier I goal ([www.vims.edu/bio/sav/](http://www.vims.edu/bio/sav/))). (Figure UWS13). Due to flight restrictions following the September 11, 2001 terrorist attacks, no data were collected for 2001. Most of the SAV in 2000 was mapped at the mouth of the river, particularly Galloway Creek. Ground-truthing by the Army Corps of Engineers staff and citizens has found 7 species of SAV in this area, listed here by frequency of occurrence: milfoil, horned pondweed, coontail, elodea, wild celery, redhead grass and curly pondweed. Data from the water quality monitoring station located near Wilson Point indicates that phosphorous passes and percent light at leaf and the concentrations of suspended solids, light attenuation and algae are borderline in respect to the habitat requirements. Nitrogen concentrations are not applicable to this oligohaline environment.



**Figure UWS13 – Submerged Aquatic Vegetation in the Upper Western Shore Basin.**

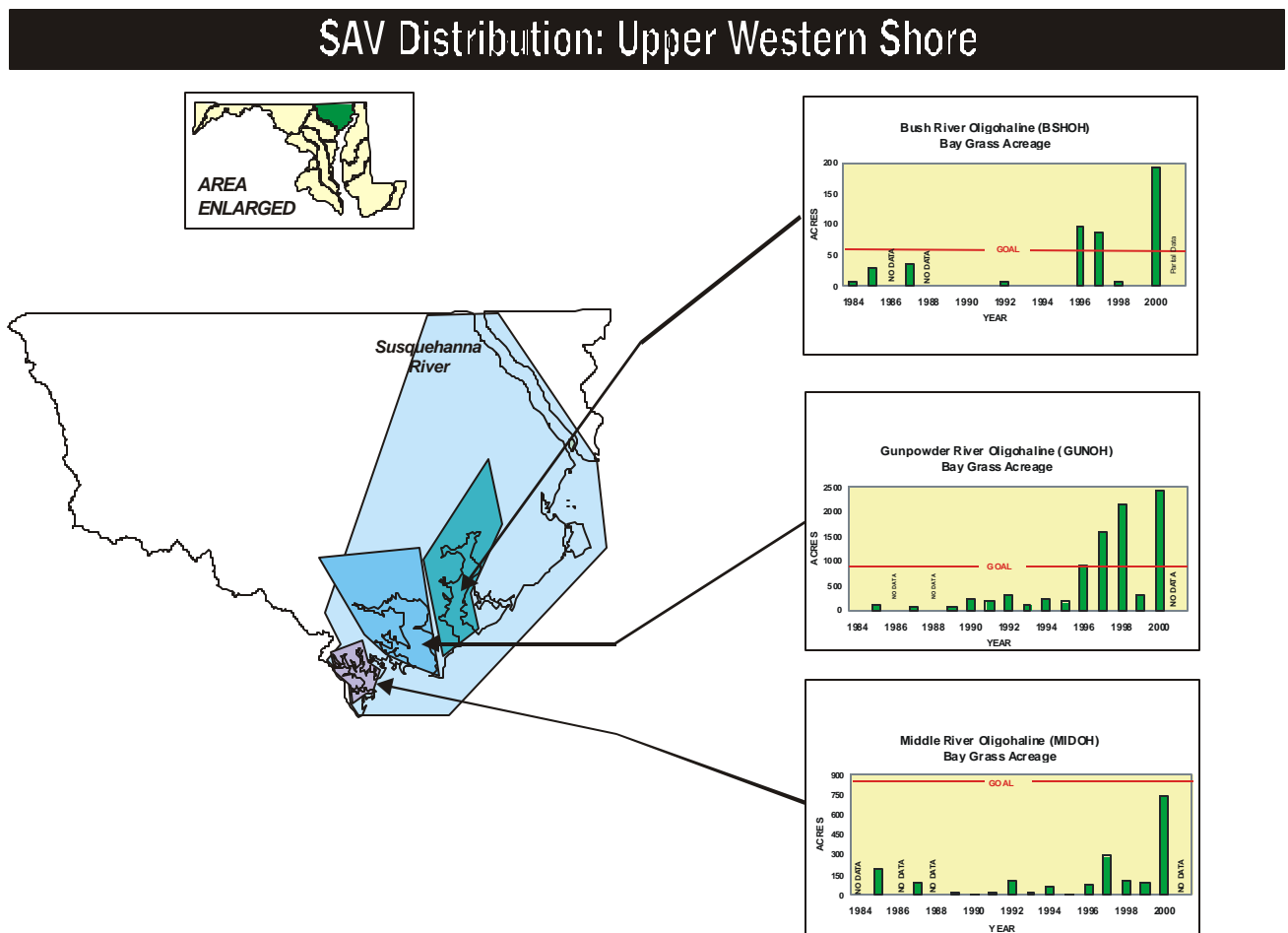


Figure 1: SAV coverage on the Upper Western Shore, 1984 to 2001

### Benthic Community

The benthic community forms an integral part of the ecosystem in estuarine systems. For example, small worms and crustaceans are key food items for crabs and demersal fish, such as spot and croaker. Suspension feeders that live in the sediments, such as clams, can be extremely important in removing excess algae from the water column. Benthic macroinvertebrates are reliable and sensitive indicators of estuarine habitat quality.

Benthic monitoring includes both probability-based sampling (sampling sites are selected at random) and fixed station sampling (the same site is sampled every year). A benthic index of biotic integrity (B-IBI) is determined for each site (based on abundance, species diversity, etc.). The B-IBI serves as a single-number indicator of benthic community health. For a more details on the methods used in the benthic monitoring program see <http://esm.versar.com/Vcb/Benthos/backgrou.htm>

Benthic community condition in Upper Western Shore basin tributaries was overall good for the period 1995-2000. During the period 1995-2000, there was no indication of stress from low dissolved oxygen (DO) in any of the Upper Western Shore basin tributaries.

The Middle and Bush River estuaries were in best condition. Probabilities of observing degraded benthos in these two tributaries were low (19 and 36 percent, respectively, Table 1). Three of the six sites that failed the B-IBI in these two systems were only marginally to moderately degraded. All degraded sites in the Bush River were located in the upper reaches of the estuary and were numerically dominated by pollution-tolerant organisms, mostly tubificid oligochaetes. This is consistent with poor water quality status for chlorophyll *a* and Secchi depth in this region of the river. Good benthic community condition in the Middle River is also consistent with observations of good water quality status for this river.

The Gunpowder River estuary was in worst condition, with a probability of observing degraded benthos of 50 percent (Table 1). However, most failing sites were only moderately degraded. One site in the lower portion of the Gunpowder River exhibited very high densities of the clam *Rangia cuneata* (20,000 individuals per m<sup>2</sup>), which may be related to the high chlorophyll values observed in this portion of the estuary.

#### Nutrient Limitation

Like all plants, phytoplankton need nitrogen, phosphorus, light, and suitable water temperatures to grow. If light is adequate and the water temperature is appropriate, phytoplankton will continue to grow as long as unlimited amounts of nutrients are available. If nutrients are not unlimited, then the ratio of nitrogen to phosphorus affects phytoplankton growth. (Phytoplankton generally use nitrogen and phosphorus at a ratio of 16:1, that is, 16 times as much nitrogen is needed as phosphorus.) If one of the nutrients is not available in the adequate quantity, phytoplankton growth is 'limited' by that nutrient. If both nutrients are available in enough excess (regardless of the relative proportion of them) that the phytoplankton can not use them all even when they are growing as fast as they can under the existing temperature and light conditions, then the system is 'nutrient saturated.'

Nitrogen limitation occurs when there is insufficient nitrogen, i.e., there is excess phosphorus. Nitrogen limitation often happens in the summer and fall after stormwater flows are lower (so less nitrogen is being added to the water) and some of the nitrogen has already been used up by phytoplankton growth during the spring. If an area is nitrogen limited, then adding nitrogen will increase phytoplankton growth.

Phosphorus limitation occurs when there is insufficient phosphorus, i.e. there is excess nitrogen. If an area is phosphorus limited, then adding phosphorus will increase phytoplankton growth. Phosphorus limitation occurs in some locations in the spring when large amounts of nitrogen are added to the estuary from stormwater flow.

If an area is light limited, then both nitrogen and phosphorus are available in excess and a situation of nutrient saturation occurs. In this case, if phytoplankton are exposed to

appropriate water temperatures and sufficient light, they will grow. If an area is both nitrogen and phosphorus limited, then both nitrogen and phosphorus must be added to increase algal growth.

Managers can use the nutrient limitation model to predict which nutrient is limiting at a given location and use the information to assess what management approach might be the most effective for controlling excess phytoplankton growth. If an area is phosphorus limited, then reducing phosphorus will bring the most immediate reductions in phytoplankton growth. However, if nitrogen levels are not also reduced, the excess nitrogen that goes unused can be exported downstream. This excess nitrogen may reach an area that is nitrogen limited, fueling phytoplankton growth in that downstream area.

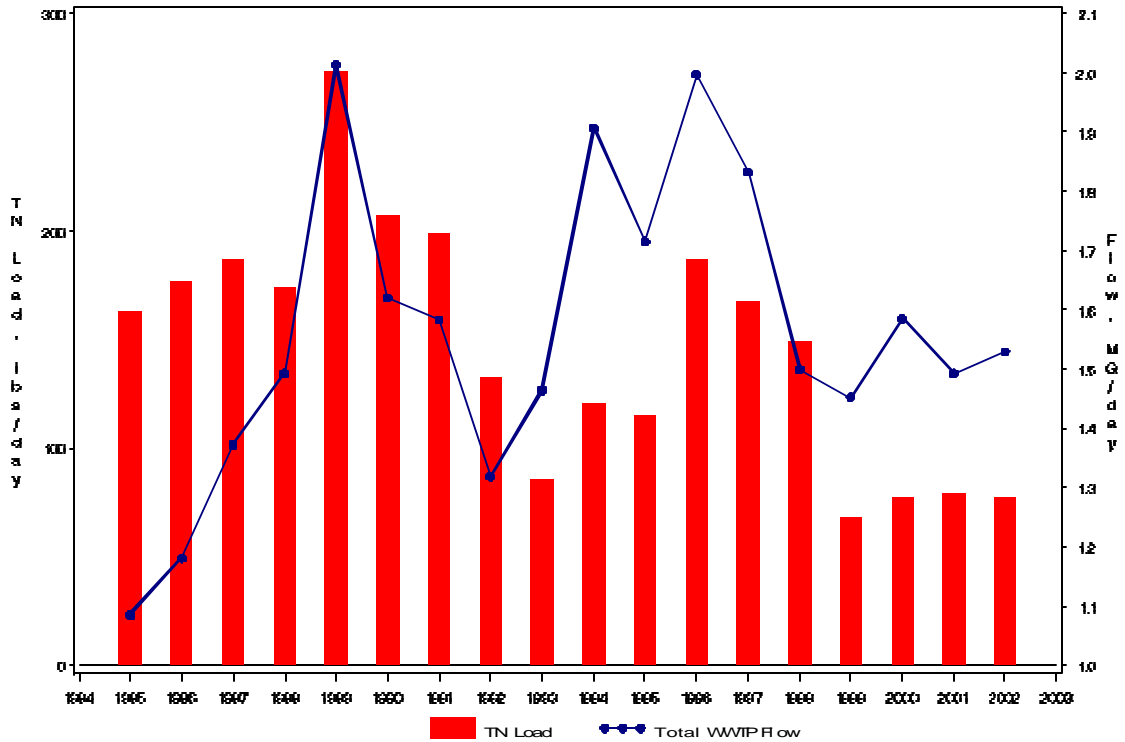
The nutrient limitation predictions are a valuable tool, but they must be used in conjunction with other water quality and watershed information to fully assess and evaluate the best management approach.

The resource limitation models were used to predict resource limitation for the three stations in the Upper Western Shore Basin. Results are summarized for the most recent three-year period (2000-2002) by season: winter (December-February), spring (March-May), summer (July-September) and fall (October-November). Managers can use these predictions to assess what management approach will be the most effective for controlling excess phytoplankton growth. Interpreting the results can be a little counter-intuitive, however. Remember that nitrogen limited means that *phosphorus* is in excess. Initially, it would seem that the best management strategy would be to reduce phosphorus inputs. However, it may actually be more cost effective to further reduce *nitrogen* inputs to increase the amount of 'unbalance' in the relative proportions of nutrients so that phytoplankton growth is even more limited. When used along with other information available from the water quality and watershed management programs, these predictions will allow managers to make more cost-effective management decisions.

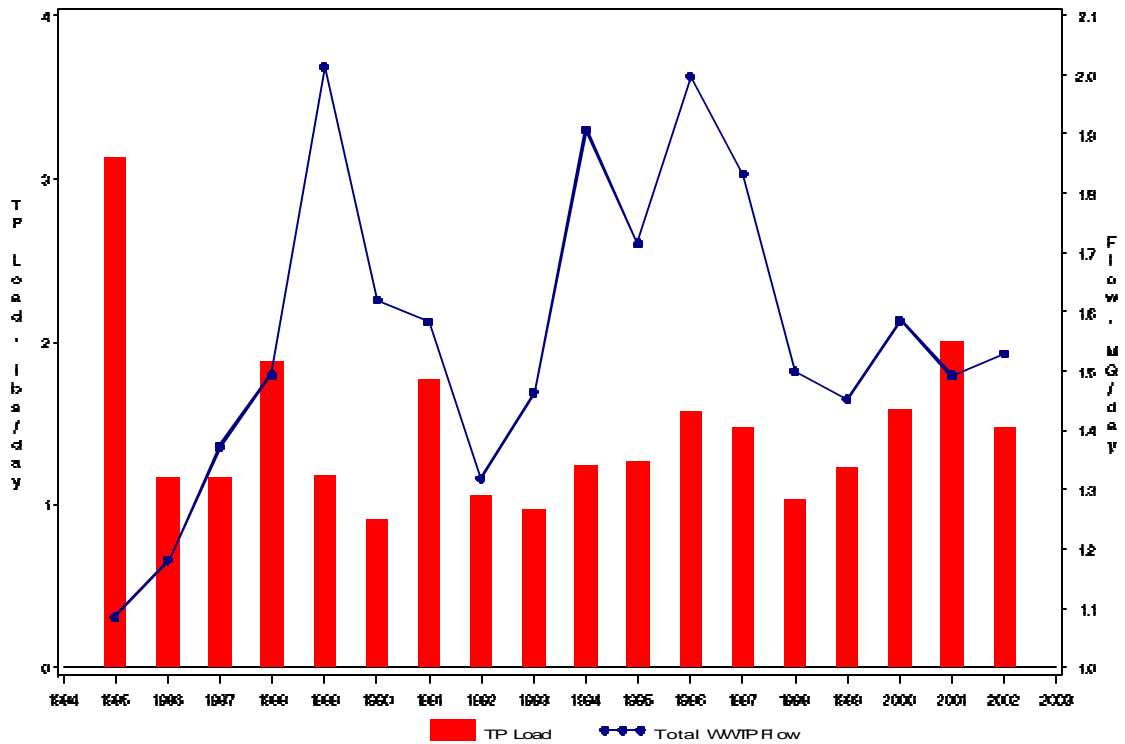
See Appendix B for details.

## **Appendix A – Nutrient Loads from Major WWTPs in the Upper Western Shore**

**ABERDEEN Wastewater Treatment Plant: Upper Western Shore Tributary Strategy Basin**  
**Mean Daily Total Nitrogen Loads and Flow**

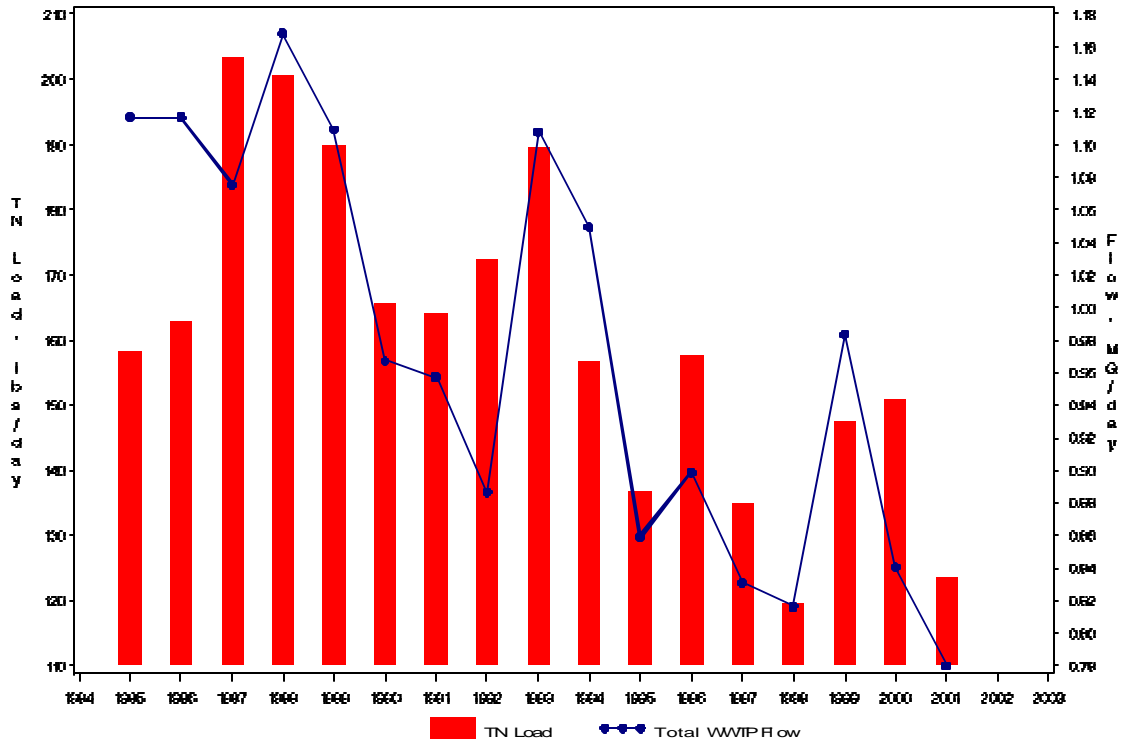


**ABERDEEN Wastewater Treatment Plant: Upper Western Shore Tributary Strategy Basin**  
**Mean Daily Total Phosphorus Loads and Flow**

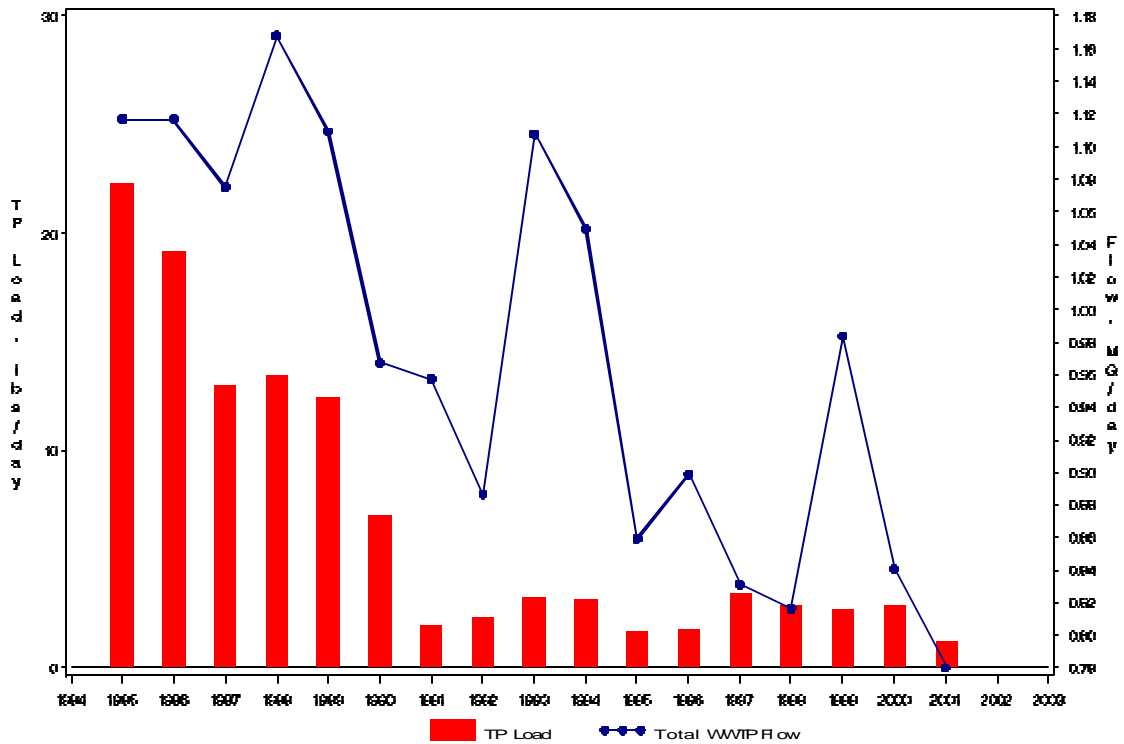




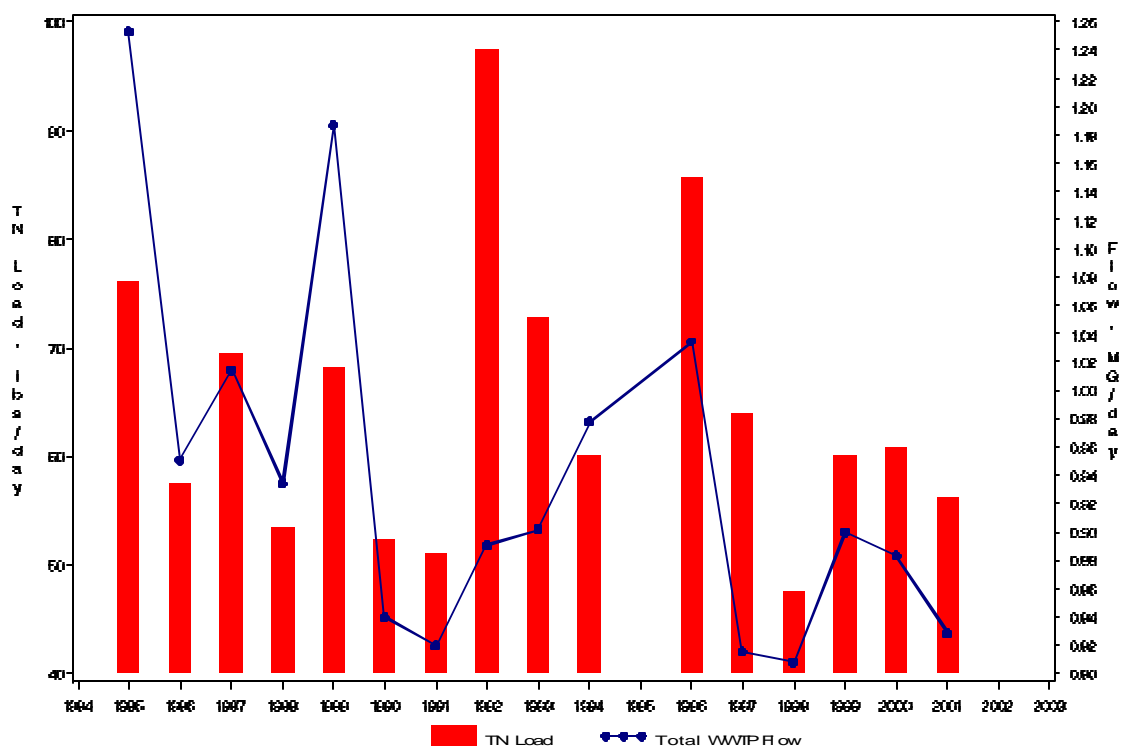
APG—ABERDEEN Wastewater Treatment Plant: Upper Western Shore Tributary Strategy Basin  
Mean Daily Total Nitrogen Loads and Flow



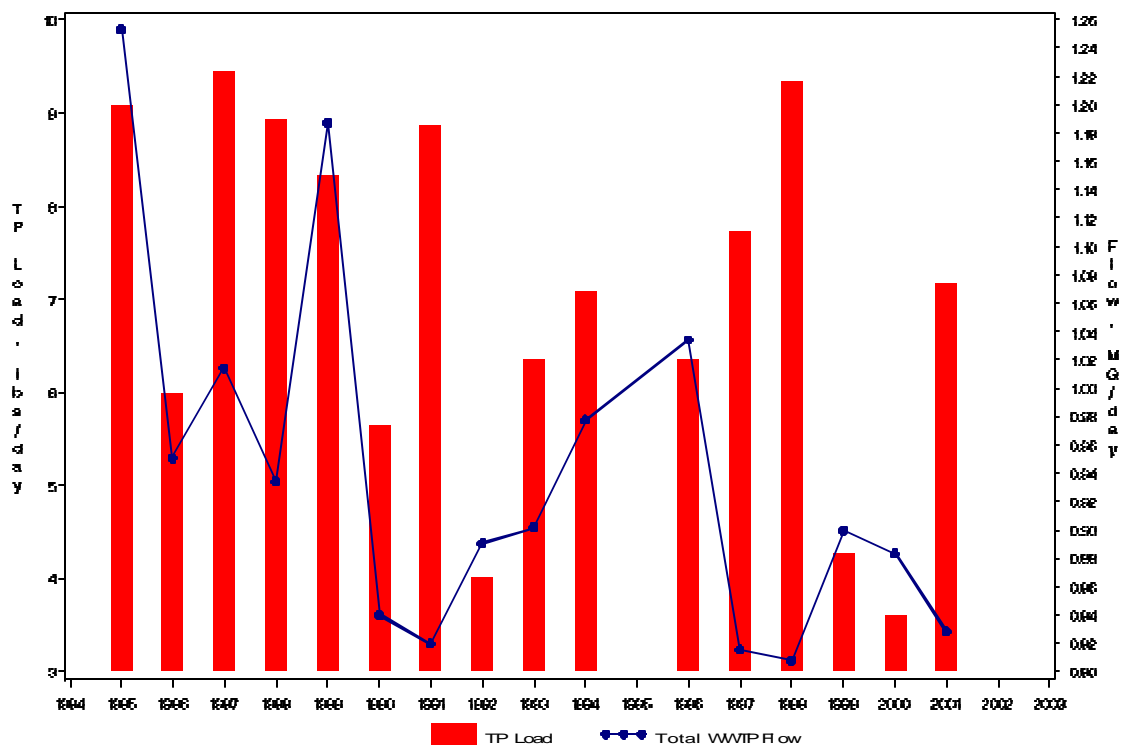
APG—ABERDEEN Wastewater Treatment Plant: Upper Western Shore Tributary Strategy Basin  
Mean Daily Total Phosphorus Loads and Flow



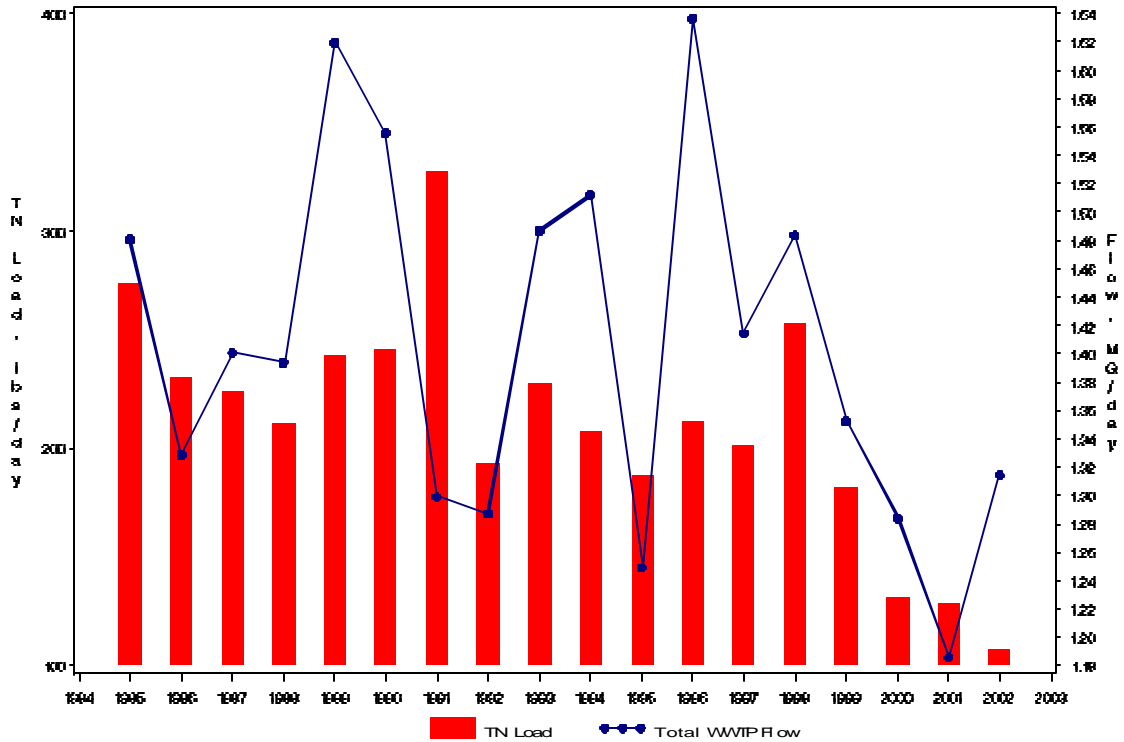
APG—EDGEWOOD Wastewater Treatment Plant: Upper Western Shore Tributary Strategy Basin  
Mean Daily Total Nitrogen Loads and Flow



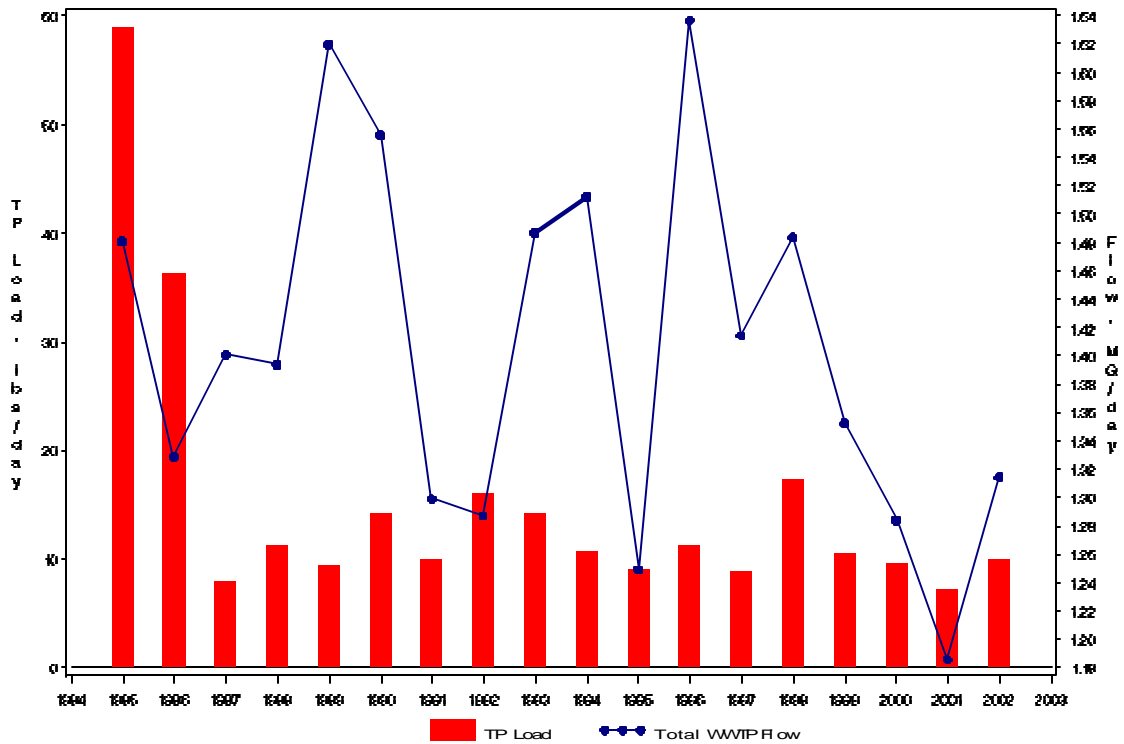
APG—EDGEWOOD Wastewater Treatment Plant: Upper Western Shore Tributary Strategy Basin  
Mean Daily Total Phosphorus Loads and Flow



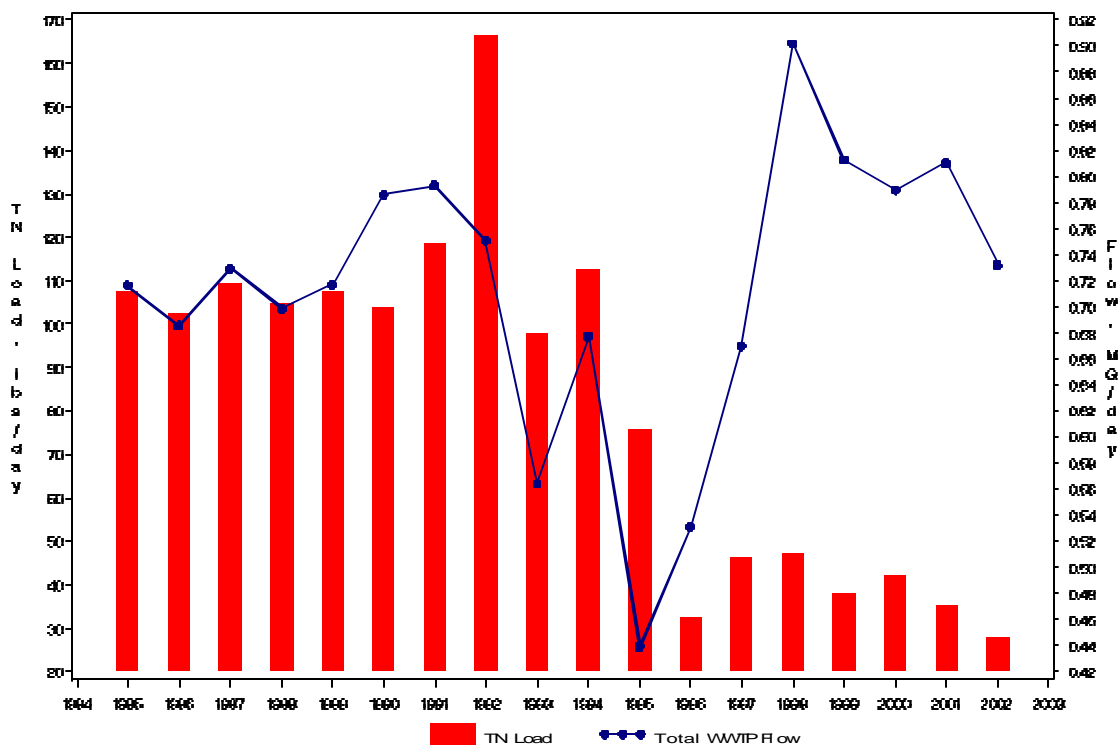
HAVRE DE GRACE Wastewater Treatment Plant: Upper Western Shore Tributary Strategy Basin  
Mean Daily Total Nitrogen Loads and Flow



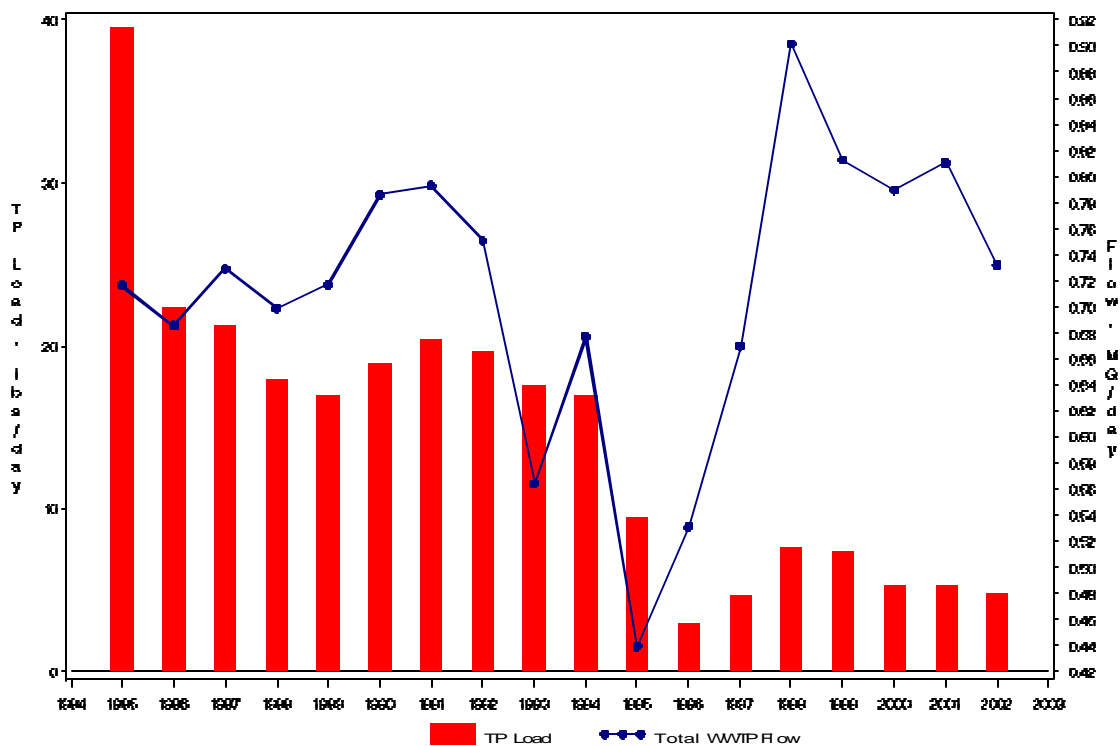
HAVRE DE GRACE Wastewater Treatment Plant: Upper Western Shore Tributary Strategy Basin  
Mean Daily Total Phosphorus Loads and Flow



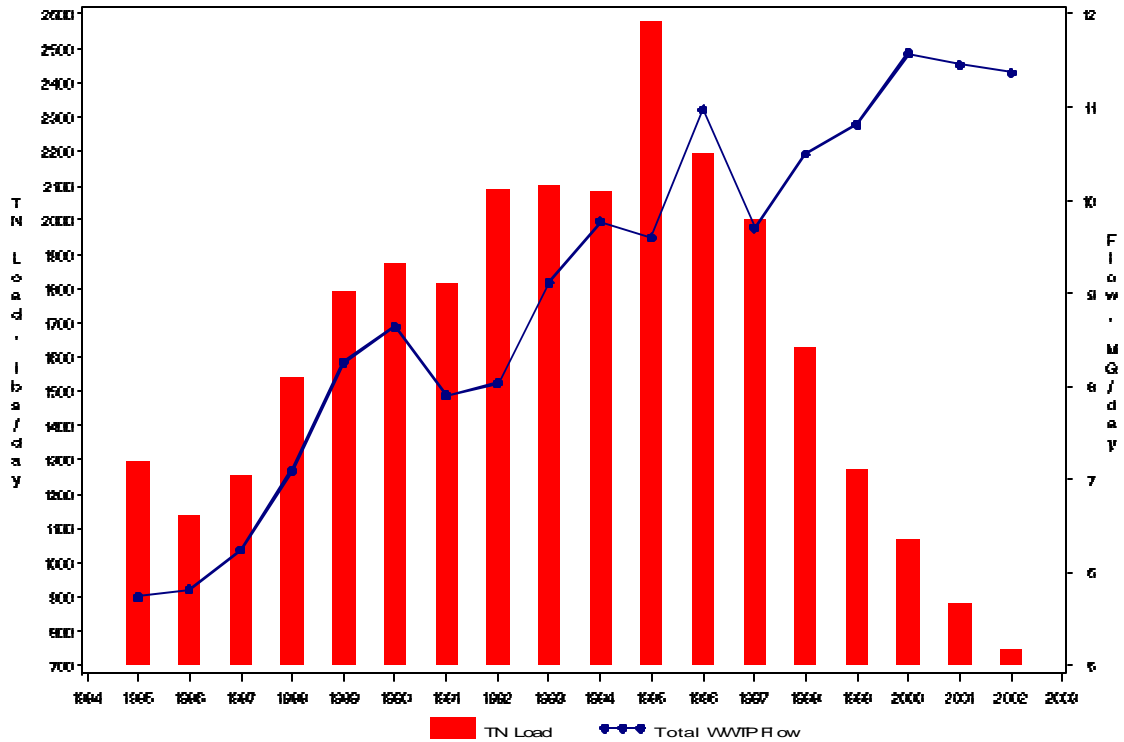
JOPPATOWNE Wastewater Treatment Plant: Upper Western Shore Tributary Strategy Basin  
Mean Daily Total Nitrogen Loads and Flow



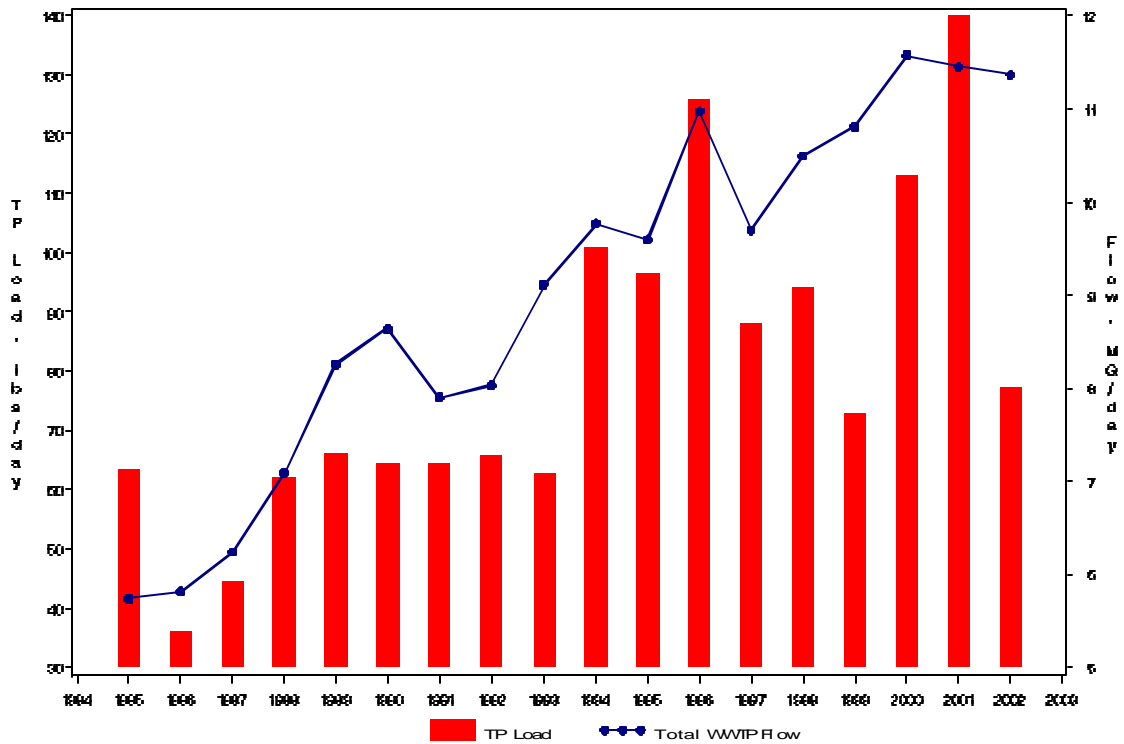
JOPPATOWNE Wastewater Treatment Plant: Upper Western Shore Tributary Strategy Basin  
Mean Daily Total Phosphorus Loads and Flow



**SOD RUN Wastewater Treatment Plant: Upper Western Shore Tributary Strategy Basin**  
**Mean Daily Total Nitrogen Loads and Flow**



**SOD RUN Wastewater Treatment Plant: Upper Western Shore Tributary Strategy Basin**  
**Mean Daily Total Phosphorus Loads and Flow**

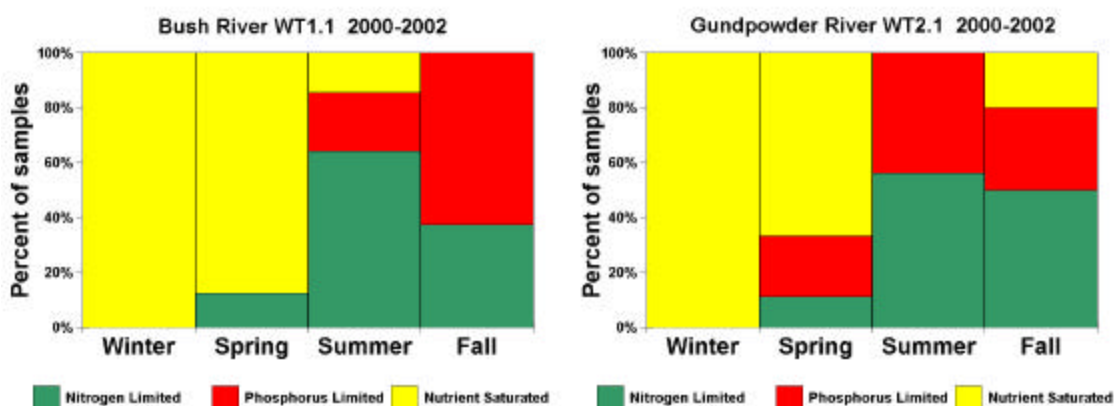




## Appendix B – Nutrient Limitation Graphs for the Upper Western Shore River Basin

The resource limitation models were used to predict resource limitation for the three stations in the Upper Western Shore Basin. Results are summarized for the most recent three-year period (2000-2002) by season: winter (December-February), spring (March-May), summer (July-September) and fall (October-November). Managers can use these predictions to assess what management approach will be the most effective for controlling excess phytoplankton growth. Interpreting the results can be a little counter-intuitive, however. Remember that nitrogen limited means that *phosphorus* is in excess. Initially, it would seem that the best management strategy would be to reduce phosphorus inputs. However, it may actually be more cost effective to further reduce *nitrogen* inputs to increase the amount of ‘unbalance’ in the relative proportions of nutrients so that phytoplankton growth is even more limited. When used along with other information available from the water quality and watershed management programs, these predictions will allow managers to make more cost-effective management decisions.

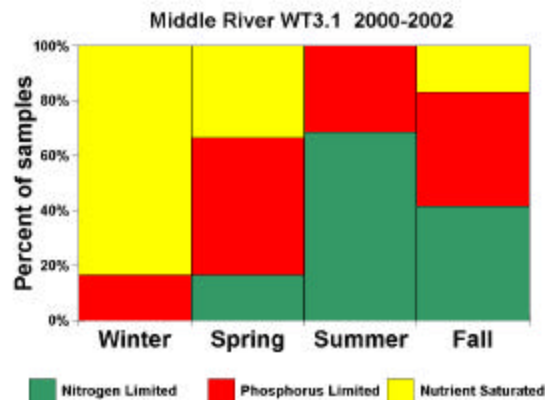
Bush River (WT1.1) - On an annual basis, phytoplankton growth is nitrogen limited almost 30% of the time and phosphorus limited more than 15% of the time. Winter growth is entirely nutrient saturated (light limited or no limitation). Spring growth is nitrogen limited more than 10% of the time and nutrient saturated the remainder of the time. Summer growth is nitrogen limited about 65% of the time and phosphorus limited more than 20% of the time. Fall growth is phosphorus limited more than 60% of the time and nitrogen limited more than 35% of the time. Relative status of total nitrogen, dissolved inorganic nitrogen, total phosphorus and dissolved inorganic phosphorus concentrations are good; dissolved inorganic nitrogen concentration is improving (decreasing). Dissolved inorganic nitrogen to dissolved inorganic phosphorus ratio is decreasing; still, this ratio is relatively very high in winter, indicating that decreases in phosphorus will help limit phytoplankton growth in this season. Further reductions in nitrogen concentration will enhance nitrogen limitation throughout the year.



Gunpowder River (WT2.1) - On an annual basis, phytoplankton growth is nitrogen limited 30% of the time and phosphorus limited 25% of the time. Winter growth is entirely nutrient saturated (light limited or no limitation). Spring growth is phosphorus limited more than 20% of the time and nitrogen limited 10% of the time. Summer

growth is nitrogen limited about 55% of the time and phosphorus limited almost 45% of the time. Fall growth is nitrogen limited 50% of the time and phosphorus limited 30% of the time. Relative status of total nitrogen, dissolved inorganic nitrogen, total phosphorus and dissolved inorganic phosphorus concentrations are all good; total nitrogen concentration is improving (decreasing). Dissolved inorganic nitrogen to dissolved inorganic phosphorus ratio is decreasing; this ratio is relatively high in winter and relatively low in fall. This indicates that reductions in both nitrogen and phosphorus, especially in these seasons, have the potential to limit algal growth locally in the Gunpowder River.

Middle River (WT3.1) – On an annual basis, phytoplankton growth is nitrogen limited more than 30% of the time and phosphorus limited more than 35% of the time. Growth in the winter is more than 15% phosphorus limited and otherwise is nutrient saturated (light limited or no limitation). Growth in the spring is phosphorus limited 50% of the time and nitrogen limited more than 15% of the time. Growth in the summer is nitrogen limited almost 70% of the time and phosphorus limited more than 30% of the time. Growth in the fall is nitrogen limited more than 40% of the time and phosphorus limited more than 40% of the time. Total nitrogen, dissolved inorganic nitrogen, total phosphorus and dissolved inorganic phosphorus concentrations are all relatively good and total nitrogen and total phosphorus concentrations are improving (decreasing). The ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus is relatively high in winter and spring, as is spring dissolved nitrogen concentration, indicating that continued reductions in phosphorus, especially in the spring, have the potential to better limit phytoplankton growth locally in the Middle River. Continued reductions in nitrogen in summer and fall will also likely help further limit phytoplankton growth in these seasons.



## Appendix C – References

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